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Natural Mortality of American Shad

CHARLES H. WALBURG

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Since 1950 the Bureau of Commercial Fisheries has studied the American shad (*Alosa sapidissima*) of the Connecticut River to obtain information whereby the population may be managed to obtain optimum sustained yields. A necessary part of these investigations is the determination of the natural mortality of adult fish.

Few studies have been conducted to determine natural mortality of shad. Fredin (1954) compared the estimated abundance of 6- to 7-year-old fish collected in the Connecticut River in 1946 and 1947, and estimated that the extraneous mortality rate (deaths occurring between fishing seasons) was 36 percent. Talbot and Sykes (1958) reported that adult shad native to streams south of Cape Hatteras, North Carolina, die after spawning. The natural mortality of these fish after initial spawning is presumed to be 100 percent.

In the Connecticut River over 80 percent of the fluctuations in size of runs can be attributed to changes in the size of the escapement from the fishery (Fredin, 1954). Therefore, the number of progeny is dependent on the size of the spawning stock. Using catch and effort statistics supplied by the Connecticut State Board of Fisheries and Game, Fredin presented a method whereby total effort in standard fishing units, fishing mortality rate, and population size could be determined annually. These data are available for each year 1935 to 1959.[2]

In addition to the Connecticut River fishery, shad native to this stream are captured along their ocean migration routes from North Carolina to Maine (Talbot and Sykes, 1958). It was estimated by Nichols (1958) that approximately 13 percent of the 1956 shad catch taken by the New York–New Jersey ocean pound-net fishery (16,000 fish) was native to the Connecticut River. It was further pointed out by Nichols that each year during the summer and fall, large numbers of ocean-migrant shad are taken incidentally in the Gulf of Maine by purse seiners.

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[1] Part of the shad investigation being conducted by the Bureau of Commercial Fisheries to furnish information to the Atlantic States Marine Fisheries Commission.

[2] 1935–51, Fredin (1954); 1952–59, unpublished data, Bureau of Commercial Fisheries Biological Laboratory, Beaufort, North Carolina.

TABLE 1.—*Number of shad in each age group caught per 100 standard units of fishing effort, Connecticut River*

Year	Age group						
	III	IV	V	VI	VII	VIII	IX
1956	25	2,202	1,698	1,913	283	25	0
1957	114	975	5,448	1,485	545	193	18
1958	19	1,714	2,775	3,983	720	419	78
1959	18	1,039	4,417	2,728	816	223	46
Average number	44	1,482	3,584	2,527	591	215	36
Natural log of average number	3.784	7.301	8.184	7.835	6.382	5.371	3.584

TABLE 2.—*Number of shad in each spawning group[1] caught per 100 standard units of fishing effort, Connecticut River*

Year	Spawning marks					
	0	1	2	3	4	5
1956	3,610	1,849	639	146	34	0
1957	5,413	2,221	891	217	111	0
1958	4,200	3,250	1,671	610	153	42
1959	4,337	3,271	1,297	338	100	39
Average number	4,390	2,648	1,124	328	100	20
Natural log of average number	8.387	7.909	7.025	5.793	4.605	2.996

[1] Spawning group denotes number of spawning marks.

Causes of mortality of adult shad native to the Connecticut River, exclusive of that from fishing within the river, are: (1) natural causes during or following spawning within the river; (2) natural causes at sea; and (3) fishing outside of the river. These mortalities were grouped and termed natural mortality. The natural mortality rate plus the river fishing mortality rate is equivalent to the total mortality rate (Ricker, 1958). Since annual estimates of the fishing mortality rate are available, the natural mortality rate can be determined if the total mortality rate is known.

MATERIALS

Shad scales were collected in the Connecticut River throughout the 1956–59 fishing seasons (April 1 to June 15 of each year) to obtain samples which were representative of the catch. From 1956 through 1959, 720, 531, 582, and 616 shad were sampled in the respective years. Length, weight, and sex were determined, and plastic impressions of two scales from each fish were read by two biologists using an Eberbach projector. Less than 1 percent of the scales were discarded as unreadable. Total age and number of times spawned were determined for all fish. Annuli and spawning marks as age indicators of shad have been validated.[3]

MORTALITY DETERMINATIONS

Total mortality estimates were obtained from both age- and spawning-group frequencies during the period 1956–59. A number of assumptions underlie this method of mortality estimation. According to Rounsefell and Everhart (1953) they are: (1) annual recruitment to the population was constant at the time each age group entered the fishery; (2) ages can be deciphered with a high degree of accuracy; (3) natural mortality has been constant over the period involved; (4) fishing mortality has been uniform over the period involved; (5) mortality rate of fully vulnerable age groups is equal between age groups; and (6) age samples are representative of the vulnerable age groups. These assumptions appear reasonably satisfied in this study, but as pointed out by Ricker (1958) rarely are all the theoretical requirements fulfilled.

The catch by age and spawning group for each year adjusted to 100 standard fishing units of effort was determined (Tables 1 and 2). Because there were fluctuations in year-class strength, the age- and spawning-group distributions for the 4 years were combined to obtain an estimate of average abundance. Beverton and Holt (1956) state that average abundance can be used to obtain an approximation of total mortality if the assumption is made that natural mortality is fairly constant over the period under consideration.

Shad native to the Connecticut River spawn for the first time at 3, 4, or 5 years of age. Since age-group VI is the first age group in which practically no maiden fish occur and in which all fish are fully vulnerable to capture, only frequencies of age-groups VI through IX were used to determine total mortality rate (Table 1). Some shad spawning for the first or second time (0 or 1 spawning mark on scales) are not large enough to be fully vulnerable to capture by the commercial fishery. Only fish with two or more spawning marks, therefore, were used to determine total mortality from spawning-group frequencies (Table 2).

Total mortality rates were calculated from the average age- and spawning-group distributions by a method of Rounsefell and

[3] Judy, Mayo H. (Manuscript) Validity of age determination from scales of marked American shad. Bureau of Commercial Fisheries Biological Laboratory, Beaufort, North Carolina.

Everhart (1953). The estimated total instantaneous mortality rate was 1.35 using age-group frequencies and 1.27 using spawning-group frequencies, or an average of 1.31. The instantaneous rate was converted to an annual rate of 73 percent (Ricker, 1958). If the average annual fishing mortality rate is known for the period under consideration, then the average annual natural mortality rate can be determined from Ricker's (1958) formula:

$$a = m + n - mn$$

where a is the annual total mortality rate, m is the annual fishing mortality rate, and n is the annual natural mortality rate. From unpublished data[4] it was calculated that the average annual fishing mortality rate on shad fully vulnerable to capture (fish larger than 16.7 inches fork length) over the period 1956–59 was 36 percent (range 30–40 percent).[5] The estimated average annual natural mortality rate during the period 1956–59 was therefore 58 percent.

The high natural mortality rate of adult shad is verified by the scarcity of older age groups in the catch and the preponderance of newly matured fish. This phenomenon has been found not only for the Connecticut River population but also for all Atlantic coast populations south to Chesapeake Bay.

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CHARLES H. WALBURG

U. S. Fish and Wildlife Service
Bureau of Commercial Fisheries
Beaufort, North Carolina

[4] Bureau of Commercial Fisheries Biological Laboratory, Beaufort, North Carolina.

[5] Includes both sport and commercially caught fish.